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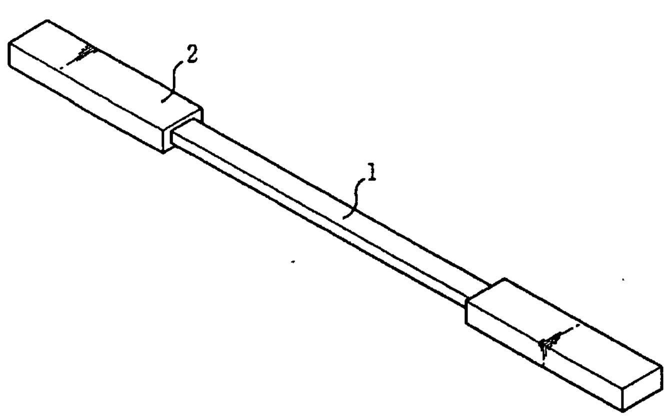
(54) Title: HIGH-TEMPERATURE CERAMIC HEATER WITH HIGH EFFICIENCY AND METHOD FOR MANUFACTURING THE SAME



(57) Abstract: Disclosed herein are a high-temperature ceramic heater with high efficiency comprising terminal zones (2) having larger diameter, and a heating zone (1) having smaller diameter, the heating zone (1) linearly interposed between both the terminal zones (2) where in the shape of the heating zone is flat-type; and a method for manufacturing the high-temperature ceramic heater. Since the high- temperature ceramic heater has broader surface area than bar-type ceramic heaters, based on the same weight, it has higher heat efficiency, and can maintain the temperature distribution within an electric furnace using it. In particular, the high-temperature ceramic heater can be manufactured using less weight of raw material than conventional bar-type ceramic heaters, based on the same surface area, which leads to light weight electric furnace. In accordance with the method for manufacturing the ceramic heater, since the heating zone and terminal zones of the ceramic heater are integrally joined through extruding and abrading processes, no cracks and separation occur in the bonding sites. Accordingly, the life span of the ceramic heater and an electric furnace using the ceramic heater can be extended. In addition, manufacturing time of the ceramic heater can be shortened because additional welding process is unnecessary. Therefore, the method for manufacturing the ceramic heater is very useful in terms of productivity.

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HIGH-TEMPERATURE CERAMIC HEATER WITH HIGH EFFICIENCY AND METHOD FOR MANUFACTURING THE SAME

Technical Field

The present invention relates to a high-temperature ceramic heater with high heat efficiency manufactured by changing the structure of conventional ceramic heaters, and a method for manufacturing the ceramic heater. More particularly, the present invention relates to a flat-type molybdenum disilicide ($MoSi_2$) heater with high heat efficiency which has broader surface area based on the same weight, improved conduction and radiation efficiency and maintains uniform temperature distribution in an electric furnace, by changing the structure of a heating zone of conventional heaters to flat-type, and a method for manufacturing the heater. In accordance with the method for manufacturing the flat-type molybdenum disilicide ($MoSi_2$) heater, a heating zone and terminal zones are integrally joined without any joining process such as welding, which improves productivity of the heater.

Background Art

Molybdenum disilicide ($MoSi_2$) is a compound consisting of molybdenum (Mo) and silicon (Si) at a molar ratio of 1:2. Since molybdenum disilicide has high thermal conductivity, low coefficient of thermal expansion, high melting point (2,030℃) and excellent oxidation resistance, it is widely used as a heater material of various industrial, experimental electric furnaces, etc. In addition, molybdenum disilicide is currently used as a heat resistant material of gas turbine, nozzle, etc.

Molybdenum disilicide ($MoSi_2$) heaters commonly consist of a heating zone (LE) having smaller diameter and terminal zones (LU) having larger diameter. Since the ceramic heater uses electrical resistance, the diameter of the terminal zones

(LU) is twice larger than that of the heating zone (LE). The molybdenum disilicide heaters are manufactured in 'U'- or 'W'-shape. An electrically connecting part coated with conductive aluminum is formed at the end portion of the terminal zones. The electrically connecting part is connected to an electrical connector which is affixed to the inner wall of a furnace.

Generally, conventional molybdenum disilicide ($MoSi_2$) heaters are manufacture by shaping a heating zone and terminal zones, respectively, and welding the respective zones. Accordingly, the molybdenum disilicide heaters are manufactured only in the form of a bar-type in terms of ease of manufacture. Welding is a very important process during manufacture of the molybdenum disilicide ($MoSi_2$) heaters. The welding process includes supplying positive charge and negative charge to the heating zone and the terminal zones, respectively, until the temperature of the bonding sites reaches the melting point of molybdenum disilicide, and integrally joining the heating zone and the terminal zones by pressurizing. However, since the welding process requires only a few ~ tens of seconds to join the heating zone and the terminal zones, cracks may occur in the bonding sites when suddenly heating or cooling. In addition, there is a disadvantage that silicon (Si), one of components contained in the ceramic heater, reacts with O_2 present in air to form an oxidation layer (silicon dioxide, SiO_2) at the bonding sites, thereby lowering the bonging strength of the heating zone and the terminal zones. Furthermore, when a sudden electrical shock is applied to the molybdenum disilicide heater, the heating zone and the terminal zones are easily separated at the bonding sites and thus the life span of the molybdenum disilicide heater becomes short. Accordingly, the use of the conventional molybdenum disilicide heaters leads to poor productivity of the electric furnace. In particular, bar-type heaters have disadvantages of increased defects due to incomplete welding.

Conventional bar-type heaters have a heating zone protruded toward the inside of an electric furnace, and terminal zones affixed to the outside of an insulating material. When the bar-type heater is used at high temperature, deformation of the heating zone may occur at the bent part ('U') of the heater or welded sites. The presence of such a deformation leads to failure of heat-treatment and even destruction of the heater. In addition, the bar-type heater has a drawback that it exhibits low heat efficiency due to its small surface area based on the same weight.

Accordingly, there is a need for ceramic heaters which have improved durability, high heat efficiency and uniform temperature distribution without no microcracks at the bonding sites of a heating zone and terminal zones.

Disclosure of the Invention

In order to solve the above-mentioned problems, the present inventor has earnestly researched to develop a novel type ceramic heater with high efficiency, and as a result, the present inventor has found that a molybdenum disilicide ($MoSi_2$) heater in which the shape of a heating zone is flat-type has broader surface area based on the same weight and high heat efficiency, and found that when a heating zone and terminal zones of the flat-type heater are integrally joined through extruding and abrading processes, no cracks occur.

Therefore, it is an object of the present invention to provide a high-temperature ceramic heater which has broad surface area and high heat efficiency without any cracks at the welded sites due to integral joint of a heating zone and terminal zones.

It is another object of the present invention to provide a method for manufacturing a high-temperature ceramic heater with improved productivity due to shortened manufacturing time without additional welding process.

Brief Description of the Drawings

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective view schematically showing the shape of a conventional bar-type molybdenum disilicide ($MoSi_2$) heater; and

Fig. 2 is a perspective view schematically showing the shape of a flat-type molybdenum disilicide ($MoSi_2$) heater according to the present invention.

Best Mode for Carrying Out the Invention

In order to achieve the objects of the present invention, there is provided a high-temperature ceramic heater with high efficiency, comprising:

terminal zones (2) having larger diameter; and

a heating zone (1) having smaller diameter, the heating zone linearly interposed between both the terminal zones (2),

wherein the shape of the heating zone (1) is flat-type.

In accordance with the present invention, the shape of the terminal zones of the ceramic heater may be bar-type or flat-type, and is preferably flat-type in terms of ease of manufacture.

Since the heating zone (LE) and the terminal zones (2) are made of the same material, they have the same specific resistance. Considering the fact that the specific resistance is inversely proportional to unit area, the area of the terminal zones (2) is designed to be larger than that of the heating zone so that the heating amount of the terminal zones (2) is low compared to that of the heating zone.

In accordance with the present invention, the heating zone (1) and the

terminal zones (2) are integrally joined each other without any bonding sites.

The term 'flat-type' used herein refers to rectangular shape such as plate, film, etc. The shape and dimension of the heating zone (1) are appropriately controlled within the range of not damaging the physical properties of the ceramic heater such as mechanical strength.

The high-temperature ceramic heater with high efficiency of the present invention having the flat-type heating zone (1) has higher homogeneity than conventional heaters having a 'U'-shape heating zone. In addition, since the ceramic heater of the present invention has broader surface area than bar-type ceramic heaters, based on the same weight, it has higher heat efficiency such as conduction and radiation efficiency. Furthermore, the ceramic heater of the present invention can maintain the temperature distribution within an electric furnace using it. In particular, the ceramic heater of the present invention can be manufactured using less weight of raw material than conventional bar-type ceramic heaters, based on the same surface area, which is economically advantageous.

The high-temperature ceramic heater of the present invention may be made of a ceramic material selected from compounds containing silicon (Si) or silicon disilicide (SiO_2), SiC-based ceramic materials and ZrO_2-based ceramic materials, and is preferably made of molybdenum disilicide ($MoSi_2$).

Since the heating zone (1) and the terminal zones (2) of the high-temperature ceramic heater according to the present invention are integrally joined without bonding sites, no separation in the bonding sites between the heating zone (1) and the terminal zones (2) occurs unlike conventional ceramic heaters manufactured by welding the heating zone and the terminal zones.

In accordance with an aspect of the present invention, there is provided a method for manufacturing a high-temperature ceramic heater with high efficiency,

comprising the steps of:

(1) extrusion molding raw material powder for a ceramic heater to be manufactured to have a predetermined shape;

(2) cutting the extruded product into a desired length, and abrading an inner zone of the extruded product to form a heating zone; and

(3) sintering the abraded product.

In step (1) above, first raw material powder for a ceramic heater to be manufactured is placed in an extruder equipped with a vacuum apparatus. The raw material powder is then pressed by a screw of the extruder, and discharged out through a die of the extruder. The shape of the finally extruded product is determined by the shape of the die. In the present invention, the shape of the extruded product is preferably rod or bar.

In step (2) above, the heating zone (1) is formed by abrading an inner zone of the extruded product to have a rectangular shape, and thus is interposed between both terminal zones (2).

The sintering step (3) is carried out to densify the structure of the ceramic heater to be manufactured, and to increase mechanical strength of the ceramic heater. For effective and stable heating of the ceramic heater at high temperature, the sintering step is carried out at 1350~1800℃ for 30 minutes ~ 2 hours.

The method for manufacturing the ceramic heater of the present invention can shorten manufacturing time without additional welding process, and facilitates the manufacture because unnecessary steps such as preheating, slow cooling treatment and post-treatment of welded sites are eliminated. In particular, since no separation in the bonded sites between the heating zone (1) and the terminal zones (2) occurs, the ceramic heater of the present invention has improved durability and thus has extended life span.

In accordance with the method of the present invention, since the shape of the heating zone (1) is flat-type, the high-temperature ceramic heater of the present invention has broader surface area based on the same weight and higher heat efficiency than conventional bar-type ceramic heaters. In addition, since the flat-type high-temperature ceramic heater of the present invention is manufactured in the linear form, it has no bent parts unlike conventional 'U'-shaped heaters and thus has uniform density throughout the length of the ceramic heater. Furthermore, since the high-temperature ceramic heater of the present invention is manufactured through sintering, the structure of the ceramic heater becomes dense and thus the temperature distribution of the heating zone (1) is uniformly maintained. Accordingly, the use of the ceramic heater of the present invention increases the heat efficiency in the electric furnace.

Conventional ceramic heaters have fine gaps formed between the heating zone (1) and the terminal zones (2). Since these fine gaps inhibit thermal conductivity, partly apply thermal stress to the zones, and finally propagate the microcracks in the welded parts (3), causing defects of the heater. The high-temperature ceramic heater of the present invention has no fine gaps between the heating zone (1) and the terminal zones (2), thermal conductivity is improved.

Conventional 'U'- or 'W'-shape ceramic heaters have different structural density between an inner side and an outer side of the bent part of the heating zone (1), and the length of the inner side is shorter than that of the outer side. Accordingly, the temperature distribution in the heating zone (1) is not uniform due to the different structural density and length. In addition, since the high-temperature ceramic heater of the present invention has linear structure, the change in electrical resistance is inhibited and thus has uniform temperature distribution in the heating zone (1).

Hereinafter, the present invention will be described in more detail with reference to the following Examples. However, these examples are given for the purpose of illustration and are not to be construed as limiting the scope of the invention.

Example

Example 1: Manufacture of molybdenum disilicide ($MoSi_2$) heater (1)

After 40kg of molybdenum disilicide ($MoSi_2$) powder (particle size: < 20μm) was charged into a hopper of an extruder equipped with a heating apparatus, the molybdenum disilicide ($MoSi_2$) powder was extruded under pressure of a screw in the extruder. The extruded material was discharged out through a rectangular die (4(*W*) x 12(*D*) x 300mm) and cooled. The extrusion was carried out under the following operational conditions:

Temperature of die: 20~30℃

Extrusion rate: 400mm/min.

The cooled product was cut to a length of 350mm using a cutter, a heating zone (1) was abraded to a dimension of 3mm(*W*) x 9.4mm(*D*) x 200mm(*L*), sintered at 1800℃ for 2 hours, and cooled to room temperature to manufacture a flat-type molybdenum disilicide ($MoSi_2$) heater.

Example 2 : Manufacture of molybdenum disilicide ($MoSi_2$) heater (2)

A molybdenum disilicide heater was manufactured in the same manner as in Example 1, except that the heating zone was cut to a dimension of 4mm(*W*) x 7.1mm(*D*) x 200mm(*L*).

Test Example:

The surface areas of the flat-type molybdenum disilicide ($MoSi_2$) heaters manufactured in Examples 1 and 2, and a bar-type molybdenum disilicide heater having a heating zone of 6mm(Φ) x 200mm(*L*) (Comparative Example) were calculated based on the same weight (31g). The results are shown in Table 1 below. In addition, the weight of the molybdenum disilicide ($MoSi_2$) heaters manufactured in Examples 1 and 2, and the bar-type molybdenum disilicide heater was measured based on the same surface area. The results are shown in Table 2 below.

Table 1

	Dimension of heating zone	Weight (g)	Surface area (mm^2)	Increase in surface area
Comparative Example	6 x 200 (Φ x L)	31g	3,842	-
Example 1	3 x 9.4 x 200 (W x D x L)	31g	5,024	▲ 31.4%
Example 2	4 x 7.1 x 200 (W x D x L)	31g	4,482	▲ 17.2%

Table 2

	Dimension of heating zone	Surface area (mm^2)	Weight of raw material (g)	Decrease in weight of raw material
Comparative Example	6 x 200 (Φ x L)	3,842	31	-
Example 1	3 x 9.4 x 200 (W x D x L)	3,842	23.5	▼ 24.2%
Example 2	4 x 7.1 x 200 (W x D x L)	3,842	26.5	▼ 14.9%

In the case of an electric furnace having an interior volume of 200 x 200 x

200 (mm^3), the total surface area to be occupied by heaters is 8×10^6 (mm^3). Among the total surface area, the surface area to be occupied by one bar-type heater was 2.1 (mm^2), while the surface area by one flat-type ceramic heater of Example 1 was 1.6 (mm^2). Accordingly, the heat efficiency of the flat-type ceramic heater of the present invention was increased by 30% or more. This result suggests that the number of the heater according to the present invention can be reduced, compared to that of the conventional heater, and that load of the heater according to the present invention can be decreased, which extends the life span of the heater.

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible.

Since the flat-type ceramic heater of the present invention has broader surface area than bar-type ceramic heaters, based on the same weight, it has higher heat efficiency, and can maintain the temperature distribution within an electric furnace using it. In particular, the ceramic heater of the present invention can be manufactured using less weight of raw material than conventional bar-type ceramic heaters, based on the same surface area, which leads to light weight electric furnace.

In accordance with the method for manufacturing the ceramic heater of the present invention, since the heating zone and terminal zones of the ceramic heater are integrally joined through extruding and abrading processes, no cracks occur in the bonding sites. Accordingly, the life span of the ceramic heater and an electric furnace using the ceramic heater can be extended. In addition, manufacturing time of the ceramic heater can be shortened because additional welding process is unnecessary. Therefore, the method for manufacturing the ceramic heater is very useful in terms of productivity.

Claims:

1. A high-temperature ceramic heater with high efficiency, comprising:

terminal zones having larger diameter; and

a heating zone having smaller diameter, the heating zone linearly interposed between both the terminal zones,

wherein the shape of the heating zone is flat-type.

2. The high-temperature ceramic heater according to claim 1, wherein the heating zone and the terminal zones are integrally joined each other without any bonding sites.

3. The high-temperature ceramic heater according to claim 1 or 2, wherein the shape of the terminal zones is bar-type or flat-type.

4. The high-temperature ceramic heater according to claim 1, wherein the heating zone and the terminal zone are made of a ceramic material selected from compounds containing silicon (Si) or silicon disilicide (SiO_2), SiC-based ceramic materials and ZrO_2-based ceramic materials.

5. The high-temperature ceramic heater according to claim 1, wherein the heating zone and the terminal zone are made of molybdenum disilicide ($MoSi_2$).

6. A method for manufacturing a high-temperature ceramic heater, comprising the steps of:

(1) extrusion molding raw material powder for a ceramic heater to be

manufactured to have a predetermined shape;

(2) cutting the extruded product into a desired length, and abrading an inner zone of the extruded product to form a heating zone; and

(3) sintering the abraded product.

7. The method for manufacturing a high-temperature ceramic heater according to claim 6, wherein the shape of the product extruded in step (1) is rod or bar.

8. The method for manufacturing a high-temperature ceramic heater according to claim 6, wherein the heating zone is abraded to have a rectangular shape and interposed between both terminal zones.

9. The method for manufacturing a high-temperature ceramic heater according to claim 6, wherein the sintering step (3) is carried out at 1350~1800℃ for 30 minutes ~ 2 hours.

FIG. 1

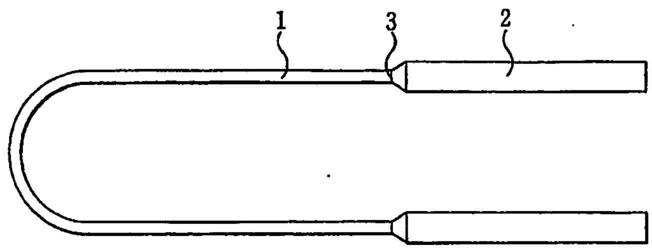
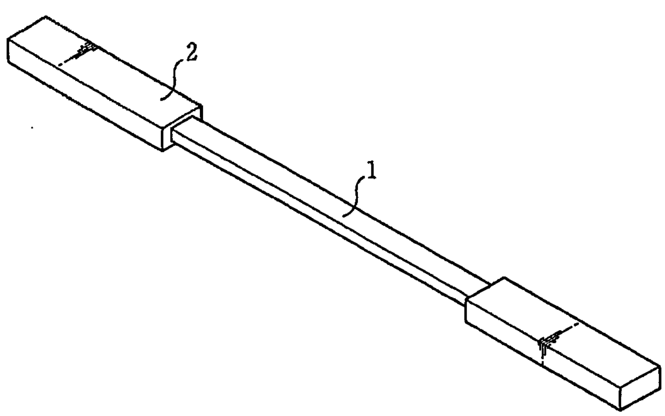


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC7 H05B 3/10, H05B 3/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean patents and application since 1975
Korean utility models and application for utility models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
"Y"	JP 10-324571 A2 (RIKEN CO) 08, DEC. 1998 WHOLE DOCUMENT	1-5
"A"	JP 05-36470 A (KYOCERA CO) 12, FEB. 1993 WHOLE DOCUMENT	1-9
"A"	JP 09-132460 A (RIKEN CO) 20, MAY. 1997 WHOLE DOCUMENT	1-9
"A"	JP 02-227981 A (SHINAGAWA REFRACT CO) 11, SEP. 1990 WHOLE DOCUMENT	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 JUNE 2003 (14.06.2003)	17 JUNE 2003 (17.06.2003)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
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